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# EFFECTS OF INCENTIVE CONTRACTS IN RESEARCH AND DEVELOPMENT: A PRELIMINARY RESEARCH REPORT

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# Effects of Incentive Contracts in Research and Development:

## A Preliminary Research Report

by

Edward B. Roberts* and J. Barry Sloat+

## ABSTRACT

Five research and development contracts that were converted from a cost reimbursement basis to a form of incentive contract were studied by interviews with government and contractor personnel associated with the project. The analyses of these contracts indicate that during negotiations for incentive conversions, contractors avoid risk by some combination of stalling and allowing time to reduce the uncertainty or by refusing to negotiate agreements that contain cost sharing possibilities. The evidence further indicates that losses on incentive contracts are highly motivating and may lead to harmful shortcutting and work stoppage threats. It appears that contractors monitor and control contract change more carefully on incentive contracts than on CPFF contracts. However, this is seen as a mixed blessing, producing decreased technical flexibility to the government and increased need for technical negotiations, as well as the possible benefit of cost reductions. Contract change is revealed to be a major problem on technically complex and uncertain tasks and may cause contract outcome to be more a result of negotiation skills than of the operation of contractual incentives.

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# INTRODUCTION

In the past several years an effort has originated in the Defense Department (and followed by other government agencies) to discourage the use of Cost-Plus-Fixed-Fee (CPFF) contracts and substitute contractual incentive arrangements. This effort supposedly relies upon the profit motive to reduce requirements for direct government control and to stimulate better contractor performance and cost estimating. Incentive type contracts are not new in government contracting. Production contracts have been awarded on a fixed price basis for many years. The fixed price contract provides maximum correlation of contract profits with contract cost, and in theory might offer maximum cost incentive. However the use of incentive arrangements on R&D contracts is the novel feature of the DOD (and NASA) programs of the past several years.

The desirability of incentives for improved research and development performance is obviously high. Yet it is not as obvious that formal contractual forms of incentives are desirable in R&D. The issue involves managerial, political, economic and psychological questions made extremely complex by the large number of incentive arrangements possible. Conclusive evaluation of the effectiveness of incentive contracting is impeded by the scarcity of adequately documented relevant experience. This paper provides actual case evidence regarding the effects of cost incentive arrangements on the contractor-government relationship and on

contractor behavior in order to aid understanding of the results of incentive contracts as applied to development work. While there have been previous studies of incentive contracting, none have been specifically concerned, as this is, with the use of such contracts in engineering development programs.[1] For government organizations with a low volume of production contracts, notably those connected with both the civilian and military space programs, development expenditures are of major importance. The focus of this report of preliminary research is the identification of government and contractor behavioral changes caused by cost incentives in development contracts, relative to behavior that might have been exhibited had the contract been CPFF.

A difficult problem in studies of this type is the determination of what behavior might have been in the absence of the factor of interest--in this case, incentive arrangements. To overcome this problem, the study has focused on several contracts that were awarded originally on a CPFF basis and were converted, after design was underway, to a contract that in part correlated profit with cost outcome (i.e., provided formal contracted incentives). Comparison of behavior before and after conversion allows at least partial control of the contract situation so that behavioral change caused by the incentives may be identified.

Five prime R&D contracts ranging in final cost between five million and two hundred million dollars were investigated by interviews conducted

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[1] The most thorough treatment of incentives in government contracting is provided by F.M. Scherer, The Weapons Acquisition Process: Economic Incentives (Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1964). However, Scherer's data are largely derived from production contracts, not R&D.

with government and industry personnel associated with the project and contract management. In addition, data were obtained from the files of the government agencies that awarded and administered the contracts. All of the contracts were for the development of technical equipment that had never previously been produced and that represented significant advances in the state-of-the-art.

Five R&D contracts converted from CPFF to formal incentives are clearly an inadequate sample for conclusive evaluation of incentive contracting per se. Yet to the authors' knowledge there exists no other published comparative studies that examine the effects of various R&D contract forms. Much additional research is needed on the questions of contracting effectiveness. The authors hope that the observations and tentative conclusions presented in the next section will stimulate some of the required research studies.

## ANALYSES AND TENTATIVE CONCLUSIONS

Space limitations prevent detailed presentation of the history of each of the five cases investigated.[2] This section presents in summary form the general patterns motivating the conversion to incentives and the impact of conversions based on the original data of the study.

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[2] More details are available in J.B. Sloat, "Incentive Contracts for the Procurement of Research and Development: A Study of Several Cases" (unpublished Master of Science thesis, M.I.T. Sloan School of Management, 1964).

## Origin of the Incentive Contract

In all cases examined, the idea for the incentive contract was presented by the government contracting agency after a large overrun on a CPFF contract had been recognized by the company and by the government. Persons at the project level in the companies uniformly indicated that at the time of the suggestion they were opposed to the idea of conversion. They indicated that this opposition was based on recognition of substantial technical uncertainties that still existed at the time conversion was proposed. Except for one case, none of the contractors had successfully performed integrated systems testing on the equipment at the time conversion was proposed. In at least two cases the sub-systems testing program was at an early stage.

High level management, on the vice-presidential and presidential level, made the decision to enter into the incentive agreement and, in some cases, actively participated in the negotiations. In all cases this decision was affirmative. The reason for an affirmative decision, as indicated in two interviews, was a desire to keep an important customer happy.

## Establishment of Terms

### Contractor Decision Making

There were two distinct contractor top management reactions to the government proposal of an agreement providing for cost sharing. One reaction was a hesitancy to enter into a cost sharing agreement caused, as indicated in one case, by the project management's successful com-

munication to top management of the substantial risks associated with technical uncertainties and cost targets with no contingency. In other cases top management confidence in a favorable outcome was such that cost sharing was not actively resisted. This confidence was not always shared by project management. One project manager is said to have discovered with horror that management had agreed to an incentive arrangement that provided for possible cost sharing. There is substantial evidence that in no case did top management enter into an agreement providing for cost sharing when it expected out-of-pocket losses.

Tentative Conclusion. This study indicates poor communication between top management and project management sometimes has caused companies to enter unintentionally into high risk incentive agreements when the nature of this risk was actually known to persons in the company.

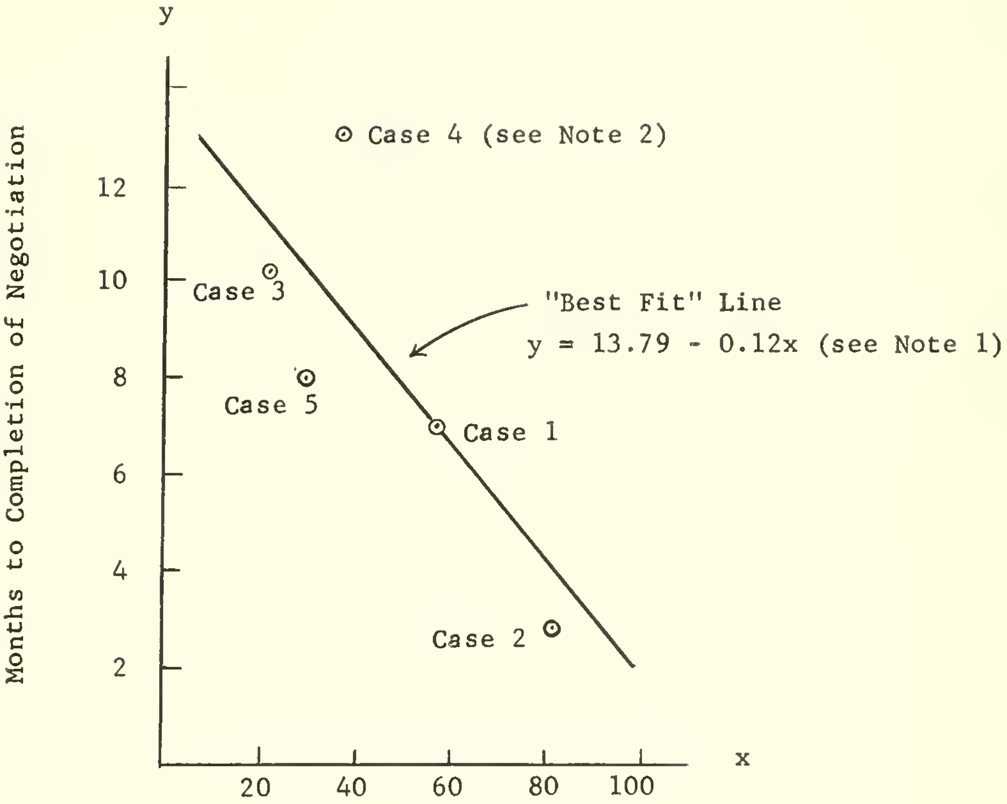
## Length of Negotiation

In most cases implementation of the general agreements reached by top management was left to lower levels in the organization although in two cases substantial early agreements appear to have been made without benefit of active lower level participation (as noted above). The expressed unhappiness of project personnel with the proposed incentive arrangement, which was due to perceived technical uncertainties, is expected to have influenced lower level negotiations. Specifically, it is expected that negotiations should have taken longest when the initial uncertainty was greatest. Technical uncertainty decreases over the life of the project and design and analysis is completed and the testing program progresses. Therefore, by merely waiting for time to pass, the contractor is in a better position with regard to possible technical problems.

To analyze this factor, accrued cost at the time of conversion as a percentage of currently expected total cost has been used as a measure of project completion. At the time this study was conducted all but one of the contracts were estimated to be over 80% complete, making the "true" cost fairly well known. The time required for agreement on the substance of the conversion--cost targets and sharing ratios--when measured from the time conversion was first suggested is inversely related to the percentage of cost incurred up to the time conversion was suggested (Figure 1). The evidence shown in the figure, and contractor statements that this is what they did, indicate that in the presence of technical uncertainties contractors respond by "stalling".

Another response to such a situation might be the refusal to agree to a contract that could result in financial penalty. Cases 2 and 5 are of this nature. Note that in Figure 1, both of these cases are lower than the "best fit" line. This indicates that they took less time to negotiate than predicted if technical uncertainty is the only variable considered and the "best fit" line is used to describe the underlying process. Thus it is indicated that the severity of the possible financial penalties in the contract has influence on the time required for agreement. A mild penalty receives more speedy negotiation than one providing for cost sharing.

Tentative Conclusion. When asked to convert cost type contracts to an incentive basis in the presence of technical uncertainties, contractors avoid the risk of financial penalty by some combination of (1) stalling and letting time reduce these uncertainties, and/or (2) refusing to negotiate agreements that can result in significant penalty (cost sharing).



Percent Complete at Conversion Suggestion

Figure 1. The Effect of Uncertainty on Negotiation Time

Note 1: The correlation coefficient of the "best fit" line is 0.75.

Note 2: In Case 4 substantial agreement was reached after three months; however, thirteen months were required to agree upon exactly what work came under that agreement.

Although the initial award of incentive contracts was not investigated in this preliminary research study, it is expected that major problems might be anticipated in the initial negotiation of incentive development contracts. The extent to which increased negotiation effort and time is required in initial incentive contracts will depend in large part on the ability of the government to use competitive pressures to expedite negotiations. Such tactics by the government might well worsen government-industry working relationships.

## Setting Cost Targets

Cost targets in three of the cases appear to have been set on a "success the first time" basis. For example, they did not allow for failure in testing, nor did they allow for the cost of rework for retesting. As a practical matter it is known that discrepancies and failures occur even in well designed equipment. If test programs never discovered problems, they would not be undertaken. In these three cases the contractors indicated little likelihood of coming out below the cost target, but expressed the hope that they might come out in the incentive range.

Several factors worked to keep the cost targets on this "first time" basis: (1) The government contracting agencies did not allow contingencies; (2) cost analysis was performed in each case by a competent technical group in the government agency (confirmed by the contractors); and (3) conversion was proposed just after a large increase in the CPFF cost-to-complete estimate. In at least one case there had been some difficulty in getting the contractor to admit and estimate the true magnitude of this CPFF increase. When conversion was proposed it was difficult for

the contractor to include hidden contingencies because of the detailed nature of the previous estimates. This probably makes the target costs "tighter" than would be the case where contracts are initially negotiated on an incentive basis.

With no allowance for error the contract assumed the character of a gamble on the outcome of the integrated systems testing that, in four cases, had not been performed successfully. The contracts, in effect, provided an automatic fee penalty (or net loss) as a result of increased costs caused by the discovery of design inadequacy. However, since in all cases design had been substantially accomplished by the time the contract was converted, there was little the contractor could do, such as hire more capable engineers, to alter the uncertain outcome.

In one case a contingency was added to the cost estimate by negotiation and the contractor indicated that there was some expectation of coming out below target.

## Sharing Arrangements

Evidence from this study suggests that contractors who face financial losses as a result of an incentive contract may act in ways that are potentially harmful to a project. One of the most important of these, the possibility of which was suggested during the interviews, is best described as taking shortcuts. Although some reduction in redundant and marginal effort is undoubtedly desirable there is a point beyond which the reduction may be harmful. Evidence suggests that excessive shortcutting may result from severe financial penalties involved in significant cost sharing.

The effect of shortcutting in design and production, if the shortcut is successful, may be a reduction in cost. If the shortcut is not successful, the deficient system may be discovered in testing. The increased costs of redesign, rework, retesting and schedule slippage are then incurred. Unfortunately, however, testing programs and quality assurance are two areas in which the evidence indicates cost cutting may first be attempted. Two contractors explicitly mentioned quality assurance when discussing cost reduction and gave the distinct impression that the quality assurance manager faces a major battle to maintain his department staffing whenever cost reduction pressure is great. A reduced testing program combined with design and production shortcutting may, therefore, result in degradation of system performance that can go undetected until too late.

The cases indicate that competent contracting agency technical personnel can guard against the harmful effects of shortcutting. This protection is not achievable by other than the best government technical organizations. In theory, performance incentives are designed to accomplish such safeguards. In practice, however, the problems of establishing and maintaining performance incentives are reported by the government agency to be great.

Although no direct evidence was obtained to explain why a contractor will take a chance of incurring long run penalties caused by poor performance, there are several possible explanations. First, the contractor is not directly reducing performance; he is behaving in a way that will merely increase the probability of reduced performance. Short run cost control pressures under the incentive arrangements may be enough to make

the gamble appear to be a reasonable one. It is also possible that the contractor (and particularly a subcontractor) may hope that malfunctions will be difficult to trace to him. After the system leaves his control many factors typically arise that are recognized to be outside of the contractor's control. These will influence system performance and make tracing the source of poor performance an exceedingly difficult task. (This situation is altered somewhat when the contractor is going to produce in quantity the system he develops.) Long run pressures also may be absent if the contractor believes that those who in the future will determine the award of R&D or other contracts in which he is interested will not learn of the performance shortfall, or if they do learn, will not substantially alter their attitude.

Another harmful reaction to unexpected cost sharing is a contractor threat to stop work based on what he perceives as intolerable financial pressure. One of the contractors in this study threatened to quit work when cost sharing had resulted in substantial loss. If work is actually stopped the delays may result in substantial cost increase in other portions of the system. In any case, the effect of such pressure on the essential rapport between the contracting parties may be disastrous. This is especially true if the outcome is perceived by the contractor to have been beyond his control. The possibility of such financial pressure is undoubtedly more of a problem with smaller contractors.

Tentative Conclusion. Contractors subject to significant losses as a result of unexpected cost sharing on development programs are highly motivated, possibly in ways harmful to the project.

## Contract Changes

In every case the contractor indicated that changes had received greater attention after the conversion, especially those changes requested by the government. "Nice to have" changes were resisted and changes in the work directed by the government were processed much more thoroughly to get target cost increases. This was the single most consistently and prominently mentioned behavioral change. It is possible (but not demonstrable) that there has been less change in the work than there would have been under a CPFF contract. The contractor interviews provide reason to believe that this change control would occur on cost incentive contracts in general and is not limited to those that have been converted.

Such a shift in contractor attitudes is not entirely beneficial. On the one hand it decreases the flexibility available to government to alter technical specifications once a project is underway. On the other hand increased pressures to force changes in target costs to accompany job changes no doubt lead to longer recurrent negotiations and increased demands on technical staff to engage in negotiation activities.

Tentative Conclusion. Contractors appear to give more attention to changes when working under incentive contracts than they do under CPFF contracts. Benefits as well as new problems are stimulated by this shift.

The government has some control of the contract cost outcome relative to the target by means of its ability to allow change-of-scope increases in target cost. The importance of changes in affecting the contract outcome depends on their cause and their size relative to the cost to complete estimates upon which the cost targets and sharing ratios are based. In

two cases (possibly three) the amount of change was or will be large. Abundant evidence regarding contractor motivation and government testimony indicates that where substantial contract scope changes have been given and/or a contract was significantly overrun, the cause was primarily due either to technical problems discovered after the contract was converted or to changes in requirements outside the control of the contractor.

The situation was further complicated by the fact that the government plays a significant role in monitoring and approving the designs of the contractor. When unanticipated problems arise in a system whose design has been approved or accepted by the government, even though there are no specification changes, there is evidence of pressure to award the contractor a change-of-scope. This occurs primarily when performance specifications are used as was done in the cases in this study. The contractors feel that the task they are required to do is defined by understandings between the government and company on technical design, and if design must be changed due to difficulties unanticipated by both parties there should be a change-of-scope, legal agreements notwithstanding.

If relief is not given there may be damage to the government-contractor relationship, even in cases where the government feels that the contractor is performing satisfactorily, due to automatic imposition of a penalty that the contractor feels is unjust and a result of factors beyond his control. In the long run, if contractors do not expect relief, they may be forced to attempt the inclusion of excessive contingencies in the cost targets of contracts awarded initially on an incentive basis. Whether this can be done successfully will depend primarily on the extent to which the government can take advantage of competitive

pressures in the contract award process. Many government officials recognize the possible validity of the above contractor argument and are aware of the possible harm to the contractor, to the government and to contractor-government relationships that may result from strict adherence to performance specifications in incentive contracts.

However, the government also recognizes (and the case studies suggest) that desirable consequences may result from being strict in contract interpretation. The contractor interviews suggested that if contractors do not expect to be relieved from the cost consequences of unfavorable technical outcomes, they may react in two ways that would affect future contract awards. One would be an industry insistence on better program and task definition in complex development jobs before agreements are signed. The other would be an attempt to reflect adequately the technical uncertainties of the job in the cost estimates by inclusion of contingencies. The difference between excessive and adequate contingencies is clearly a difficult one to define but it is desirable from the government's standpoint that the contract price reflect the probable outcome of the contract, not the lowest possible outcome.

Whatever the resolution of this dilemma, the case studies provided clear evidence that when a contractor gets into trouble and substantially exceeds the incentive target cost there are pressures on the government to bail him out, especially when the government believes that his technical performance has been satisfactory. Conversely, if the contractor comes out under the target the cases reveal the existence of pressure on government contracting officers and project monitors to be very unyielding even on legitimate contractor change requests in order to make the cost

outcome as near target as possible. Should a significant cost underrun occur, the government people interviewed suggested that the underrun may be taken by the Congress, the GAO, or agency higher-ups as indicative of "loose" cost targets and undeserved fees.

Tentative Conclusion. In large, technically complex development tasks changes can cause substantial increases in the task on which the original cost estimates are based. There is evidence that the pressures acting on the resulting contract change negotiation process tend to push the incentive contract outcome toward the target cost (but are not very effective in this tendency). It is tentatively concluded, therefore, that the cost outcome relative to target cost of an incentive contract for complex development work is probably not determined by the operation of automatic contractual incentives, but instead by the process of negotiation reflecting many subjective variables including contracting agency satisfaction with the contractor's performance.

## Contractor Behavior

### Contractor Motivation

Scherer, in a study of several production contracts, found:

> . . . examples of contractor willingness to accept lower average profit expectations to avoid risk when substantial cost uncertainties were present. . . . As one executive remarked, "We'd much rather live with a reduction in profit and not get whipped to death on cost." . . . Company representatives explained that they would gladly accept lower CPFF profit rates in exchange for the certainty that cost overruns would be fully reimbursed should they occur.[3]

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[3] Scherer, op. cit., p. 151.

For more than a decade contractors have worked under CPFF contracts that have provided for such reimbursement. The only time they have borne the costs of contracts (other than those costs that were unallowable, averaging about 2% of total cost), is when they purposely entered into cost sharing agreements because of long run benefits expected from doing a certain R&D job.

Scherer further describes what he calls a "pressure theory" to explain the behavior of production contractors who face possible financial losses. He notes that losses are highly repugnant to contractor executives, due perhaps to their implication of poor management performance. He proposes that the pressure to avoid loss must be considered in addition to the correlation of profit with cost that occurs at the margin of a contract ("reward theory") and that the strength of this pressure should increase with tight cost targets, increasing uncertainty and high sharing ratios. His evidence indicates that "contractual incentives under the pressure theory have more powerful behavioral effects than incentives under the reward theory alone".[4]

The evidence from this study of development contracts supports the hypothesis that the pressure of losses causes high contractor motivation. As noted earlier, in no case does the evidence indicate that the contractor knowingly entered into an agreement that was thought to have a high likelihood of loss. Also, there is indication of the possibility of "excessive motivation" leading to shortcutting and stop-work threats when significant contractor cost sharing occurred. Other evidence from the

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[4] Ibid., p. 231.

contractor interviews indicates that contractors are sensitive to the break-even point and view the consequences of exceeding that point as highly undesirable. One contractor explained in detail how the break-even point more than proportionally increased as a result of changes-of-scope that were fee bearing. There is clear evidence that contractors incurring losses initiated positive cost control measures.

However, in the one case where the cost target was seen by the contractor as being possible of attainment and underrun was rewarded by a 25 percent share of the cost reduction, the contractor indicated by his statements and behavior that there was a substantial attempt to reduce costs and make increased profit. It may be possible, therefore, to stimulate desirable contractor behavior with the prospect of positive profit, provided that this positive profit is seen by the contractor as being possible of attainment.

Tentative Conclusion. Out-of-pocket losses cause high, often harmful, motivation in R&D contractors. Furthermore, possibly desirable contractor behavior may be successfully caused by the prospect of attainable significantly increased profit.

## Management Attention

It was apparent from the involvement of high level persons in the contracting agency and companies that the incentive contract attracted the interest of management on the presidential and vice-presidential level. Further evidence from both contractor and government interviews indicates that there was an increase in top management attention subsequent to the incentive conversions. The specific results of this attention were not

identified by those interviewed but it was said to be beneficial to the contracting agency. However, the contracts covered by this study were among the first R&D incentive contracts issued by the government. Some of the unusual managerial attention must be attributed to the novelty and potential future importance of R&D incentive contracting.

Tentative Conclusion. Based on the evidence of increased management involvement subsequent to the conversion of a CPFF contract, it is concluded that incentive contracts have in the recent past tended to stimulate more management attention than CPFF contracts of the same size and importance. Due to limitations on the time of top management, this increase in attention must come from decreased attention to other contracts in the same organization, especially CPFF contracts. Therefore, if most of a contractor's future work is performed under incentive contracts it is expected that increased attention will not be so readily forthcoming as was noted in this study. The control of contract changes that was observed earlier may also slacken when the extraordinary management attention is withdrawn from the incentive contracts.

## Subcontracts

All major subcontracts were converted by the prime contractor from a CPFF basis to FPI or cost sharing as a result of the prime contract conversion. The reasons given were: (1) a belief that the conversion would have a beneficial effect on the subcontractors' conduct of their programs; and (2) a reluctance to get caught with an incentive contract and CPFF subcontracts.

## Cost Allocation and Control

There is some evidence of change in budgetary systems and cost control as a result of the contract conversion. In one case where the contractor thought there was a significant chance of being under the cost target he instituted new budgetary systems. In another case a contractor, highly motivated because of potential loss, instituted a cost reduction effort by spreading information about the potential loss throughout the organization.

Misallocation of incentive contract costs to CPFF contracts in order to avoid incentive contract overrun is a possibility that was suggested on several occasions but in no way confirmed (or denied) by the study.

The preceeding analysis has indicated a few of the possible difficulties with cost type incentive contracts. One of the cases in the study had a schedule incentive arrangement in addition to the cost incentives. The contractor appeared to show more interest in the schedule incentive, partly because the cost target was shown by events soon after conversion to be rather tight and difficult to make. In fact, the estimates of cost to complete exceeded the range of cost incentive application rather early after official conversion, while the schedule incentive period was far from complete. This inadequacy of incentive design provided the potential effect of a crash program, i.e. no penalties for cost overruns and high priority associated with schedule performance. There is no evidence in this case to indicate that the actual effects have been detrimental (they may have been beneficial) but this does suggest the following conclusion.

Tentative Conclusion. If incentive provisions in a multiple incentive contract are weighted to attempt to channel the contractors' efforts

to those objectives that the contracting agency feels are most important, then care must be taken to ensure that proper weighting will exist throughout the life of the contract for all reasonably expected outcomes. This may be a formidable task.

## SUMMARY AND RECOMMENDATIONS

Despite the small sample base in the research study, the evidence does clearly indicate that contractors are highly motivated by losses on incentive contracts. There is further evidence that the prospect of substantial loss may result in harmful shortcutting, work stoppage threats and destruction of essential government-contractor understandings. It is recommended, therefore, that contractor cost sharing ratios of more than a few percent be avoided in the sharing structures of incentive contracts designed to motivate desirable contractor behavior. It is further recommended that explicit consideration be given to the possibility of unforeseen technical problems when cost targets are being established for incentive contracts, to enable the design of a fee structure appropriate to the probable outcome of the contract.

The possibilities for further study on the subject of incentive contracts for research and development are extensive, some aspects now being examined by one of the authors. A fruitful area for investigation indicated during this preliminary research study is the process of contract change as it affects incentive contracts for research and development. The large number of complex and sometimes conflicting considerations that influence the change negotiation process makes such investigation

difficult. However, evidence that contract change negotiation plays a major part in the determination of incentive contract outcomes makes understanding of the process essential.

The research conducted as the basis for this paper, while too narrow and too limited to serve as justification for firm conclusions, does suggest grave doubts of the effectiveness of incentive contracting in research and development. The tentative conclusions developed from the research data indicate that formal incentive contracts for R&D work may produce: (1) good likelihood of increased negotiation time and effort; (2) possibly harmful effects of loss anticipation by contractors, somewhat counteracted by possibly desirable contractor behavior resulting from prospects of attainable significantly increased profits; (3) increased contractor (and government) concern for control of contract changes, with several attendant benefits and harms; (4) increased relative payoffs for negotiation skills rather than technical performance; (5) increased management involvement, partially at the expense of non-incentive contracts, that may decline should R&D incentive contracts become the general rule; (6) added difficulties, particularly in multiple incentive cases, of maintaining consistent and appropriate motivations throughout a contract life cycle. Clearly, more research that leads to more consistently positive results should precede the widespread mandatory adoption of formal incentive contracts in research and development work.

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